The Accidents: A Nation's Tragedy, NASA's Challenge

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Who heard the whispers that were coming from the shuttle's Solid Rocket Boosters (SRBs) on a cold January morning in 1986? Who thought the mighty Space Shuttle, designed to withstand the thermal extremes of space, would be negatively affected by launching at near-freezing temperatures? Very few understood the danger, and most of the smart people working in the program missed the obvious signs. Through 1985 and January 1986, the dedicated and talented people at the NASA Human Spaceflight Centers focused on readying the Challenger and her crew to fly a complex mission. Seventy-three seconds after SRB ignition, hot gases leaking from a joint on one of the SRBs impinged on the External Tank (ET), causing a structural failure that resulted in the loss of the vehicle and crew.

Most Americans are unaware of the profound and devastating impact the accident had on the close-knit NASA team. The loss of Challenger and her crew devastated NASA, particularly at Johnson Space Center (JSC) and Marshall Space Flight Center (MSFC) as well as the processing crews at Kennedy Space Center (KSC) and the landing and recovery crew at Dryden Flight Research Center. Three NASA teams were primarily responsible for shuttle safety—JSC for on-orbit operation and crew member issues; MSFC for launch propulsion; and KSC for shuttle processing and launch. Each center played its part in the two failures. What happened to the "Failure is not an option" creed, they asked. The engineering and operations teams had spent months preparing for this mission. They identified many failure scenarios and trained relentlessly to overcome them. The ascent flight control team was experienced with outstanding leadership and had practiced for every contingency. But on that cold morning in January, all they could do was watch in disbelief as the vehicle and crew were lost high above the Atlantic Ocean. Nothing could have saved the Challenger and her crew once the chain of events started to unfold. On that day, everything fell to pieces.

Seventeen years later, in 2003, NASA lost a second shuttle and crew—Space Transportation System (STS)-107. The events that led up to the loss of Columbia were eerily similar to those surrounding Challenger. As with Challenger, the vehicle talked to the program but no one understood. Loss of foam from the ET had been a persistent problem in varying degrees for the entire program. When it occurred on STS-107, many doubted that a lightweight piece of foam could damage the resilient shuttle. It made no sense, but that is what happened. Dedicated people missed the obvious. In the end, foam damaged the wing to such an extent that the crew and vehicle could not safely reenter the Earth's atmosphere. Just as with Challenger, there was no opportunity to heroically "save the day" as the data from the vehicle disappeared and it became clear that friends and colleagues were lost. Disbelief was the first reaction, and then a pall of grief and devastation descended on the NASA family of operators, engineers, and managers.

The Challenger Accident

Pressure to Fly

As the final flight of Challenger approached, the Space Shuttle Program and the operations community at JSC, MSFC, and KSC faced many pressures that made each sensitive to maintaining a very ambitious launch schedule. By 1986, the schedule and changes in the manifest due to commercial and Department of Defense launch requirements began to stress NASA's ability to plan, design, and execute shuttle missions. NASA had won support for the program in the 1970s by emphasizing the cost-effectiveness and economic value of the system. By December 1983, 2 years after the maiden flight of Columbia, NASA had flown only nine missions. To make spaceflight more routine and therefore more economical, the agency had to accelerate the number of missions it flew each year. To reach this goal, NASA announced an ambitious rate of 24 flights by 1990.

NASA flew five missions in 1984 and a record nine missions the following year. By 1985, strains in the system were evident. Planning, training, launching, and flying nine flights stressed the agency's resources and workforce, as did the constant change in the flight manifest. Crews scheduled to fly in 1986 would have seen a dramatic decrease in their number of training hours or the agency would have had to slow down its pace because NASA simply lacked the staff and facilities to safely fly an accelerated number of missions.

By the end of 1985, pressure mounted on the space agency as they prepared to launch more than one flight a month the next year. A record four launch scrubs and two launch delays of STS-61C, which finally launched in January 1986, exacerbated tensions. To ensure that no more delays would threaten the 1986 flight rate or schedule, NASA cut the flight 1 day short to make sure Columbia could be processed in time for the scheduled ASTRO-1 science mission in March. Weather conditions prohibited landing that day and the next, causing a slip in the processing schedule. NASA had to avoid any additional delays to meet its goal of 15 flights that year.

The agency needed to hold to the schedule to complete at least three flights that could not be delayed. Two flights had to be launched in May 1986: the Ulysses and the Galileo flights, which were to launch within 6 days of each other. If the back-to-back flights missed their launch window, the payloads could not be launched until July 1987. The delay of STS-61C and Challenger's final liftoff in January threatened the scheduled launch plans of these two flights in particular. The Challenger needed to launch and deploy a second Tracking and Data Relay Satellite, which provided continuous global coverage of Earth-orbiting satellites at various altitudes. The shuttle would then return promptly to be reconfigured to hold the liquid-fueled Centaur rocket in its payload bay. The ASTRO-1 flight had to be launched in March or April to observe Halley's Comet from the shuttle.

On January 28, 1986, NASA launched Challenger, but the mission was never realized. Hot gases from the right-hand Solid Rocket Booster motor had penetrated the thermal barrier and blown by the O-ring seals on the booster field joint. The joints were designed to join the motor segments together and contain the immense heat and pressure of the motor combustion. As the Challenger ascended, the leak became an intense jet of flame that penetrated the ET, resulting in structural failure of the vehicle and loss of the crew.

Prior to this tragic flight, there had been many O-ring problems witnessed as early as November 1981 on the second flight of Columbia. The hot gases had significantly eroded the STS-2 booster right field joint—deeper than on any other mission until the accident—but knowledge was not widespread in mission management. STS-6 (1983) boosters did not have erosion of the O-rings, but heat had impacted them. In addition, holes were blown through the putty in both nozzle joints. NASA reclassified the new field joints Criticality 1, noting that the failure of a joint could result in "loss of life or vehicle if the component fails." Even with this new categorization, the topic of O-ring erosion was not discussed in any Flight Readiness Reviews until March 1984, in preparation for the 11th flight of the program. Time and again these anomalies popped up in other missions flown in 1984 and 1985, with the issue eventually classified as an "acceptable risk" but not desirable. The SRB project manager regularly waived these anomalies, citing them as "repeats of conditions that had already been accepted for flight" or "within their experience base," explained Arnold Aldrich, program manager for the Space Shuttle Program.

Senior leadership like Judson Lovingood believed that engineers "had thoroughly worked that joint problem." As explained by former Chief Engineer Keith Coates, "We knew the gap was opening. We knew the O-rings were getting burned. But there'd been some engineering rationale that said, 'It won't be a failure of the joint.' And I thought justifiably so at the time I was there. And I think that if it hadn't been for the cold weather, which was a whole new environment, then it probably would have continued. We didn't like it, but it wouldn't fail."

Each time the shuttle launched successfully, the accomplishment masked the recurring field joint problems. Engineers and managers were fooled into complacency because they were told it was not a flight safety issue. They concluded that it was safe to fly again because the previous missions had flown successfully. In short, they reached the same conclusion each time—it was safe to fly another mission. "The argument that the same risk was flown before without failure is often accepted as an argument for the safety of accepting it again. Because of this, obvious weaknesses are accepted again and again, sometimes without a sufficiently serious attempt to remedy them or to delay a flight because of their continued presence," wrote Richard Feynman, Nobel Prize winner and member of the presidential-appointed Rogers Commission charged to investigate the Challenger accident.

Operational Syndrome

The Space Shuttle Program was also "caught up in a syndrome that the shuttle was operational," according to J.R. Thompson, former project manager for the Space Shuttle Main Engines. The Orbital Flight Test Program, which ended in 1982, marked the beginning of routine operations of the shuttle, even though there were still problems with the booster joint. Nonetheless, MSFC and Morton Thiokol, the company responsible for the SRBs, seemed confident with the design.

Although the design of the boosters had proven to be a major complication for MSFC and Morton Thiokol, the engineering debate occurring behind closed doors was not visible to the entire Space Shuttle Program preparing for the launch of STS-51L. There had been serious erosions of the booster joint seals on STS-51B (1985) and STS-51C (1985), but MSFC had not pointed out any problems with the boosters right before the Challenger launch. Furthermore, MSFC failed to bring the design issue, failures, or concern with launching in cold temperatures to the attention of senior management. Instead, discussions of the booster engines were resolved at the local level, even on the eve of the Challenger launch. "I was totally unaware that these meetings and discussions had even occurred until they were brought to light several weeks following the Challenger accident in a Rogers Commission hearing at KSC," Arnold Aldrich recalled. He also recalled that he had sat shoulder to shoulder with senior management "in the firing room for approximately 5 hours leading up to the launch of Challenger and no aspect of these deliberations was ever discussed or mentioned."

Even the flight control team "didn't know about what was lurking on the booster side," according to Ascent Flight Director Jay Greene. Astronaut Richard Covey, then working as capsule communicator, explained that the team "just flat didn't have that insight" into the booster trouble. Launch proceeded and, in fewer than 2 minutes, the joint failed, resulting in the loss of seven lives and the Challenger.

Looking back over the decision, it is difficult to understand why NASA launched the Challenger that morning. The history of troublesome technical issues with the O-rings and joint are easily documented. In hindsight, the trends appear obvious, but the data had not been compiled. Wiley Bunn noted, "It was a matter of assembling that data and looking at it [in] the proper fashion. Had we done that, the data just jumps off the page at you."

Devastated

The accident devastated NASA employees and contractors. To this day Aldrich asks himself regularly, "What could we have done to prevent what happened?" Holding a mission management team meeting the morning of launch might have brought up the Thiokol/MSFC teleconference the previous evening. "I wish I had made such a meeting happen," he lamented. The flight control team felt some responsibility for the accident, remembered STS-51L Lead Flight Director Randy Stone. Controllers "truly believed they could handle absolutely any problem that this vehicle could throw at us." The accident, however, "completely shattered the belief that the flight control team can always save the day. We have never fully recovered from that." Alabama and Florida employees similarly felt guilty about the loss of the crew and shuttle, viewing it as a personal failure. John Conway of KSC pointed out that "a lot of the fun went out of the business with that accident."

Rebounded

Over time, the wounds began to heal and morale improved as employees reevaluated the engineering design and process decisions of the program. The KSC personnel dedicated themselves to the recovery of Challenger and returning as much of the vehicle back to the launch site as possible. NASA spent the next 2½ years fixing the hardware and improving processes, and made over 200 changes to the shuttle during this downtime. Working on design changes to improve the vehicle contributed to the healing process for people at the centers.

The Crew

Following the breakup of Challenger (STS-51L) during launch over the Atlantic Ocean on January 28, 1986, personnel in the Department of Defense STS Contingency Support Office activated the rescue and recovery assets. This included the local military search and rescue helicopters from the Eastern Space and Missile Center at Patrick Air Force Base and the US Coast Guard. The crew compartment was eventually located on March 8, and NASA officially announced that the recovery operations were completed on April 21. The recovered remains of the crew were taken to Cape Canaveral Air Force Station and then transported, with military honors, to the Armed Forces Institute of Pathology where they were identified. Burial arrangements were coordinated with the families by the Port Mortuary at Dover Air Force Base, Delaware. Internal NASA reports on the mechanism of injuries sustained by the crew contributed to upgrades in training and crew equipment that supported scenarios of bailout, egress, and escape for Return to Flight.

Following the breakup of Columbia (STS-107) during re-entry over Texas and Louisiana on February 1, 2003, personnel from the NASA Mishap Investigation Team were dispatched to various disaster field offices for crew recovery efforts. The Lufkin, Texas, office served as the primary area for all operations, including staging assets and deploying field teams for search, recovery, and security. Many organizations had operational experience with disaster recovery, including branches of the federal, state, and local governments together with many local citizen volunteers. Remains of all seven crew members were found within a 40- by 3-km (25- by 2-mile) corridor in East Texas. The formal search for crew members was terminated on February 13, 2003. Astronauts, military, and local police personnel transported the crew, with honors, to Barksdale Air Force Base, Louisiana, for preliminary identification and preparation for transport. The crew was then relocated, with military honor guard and protocol, to the Armed Forces Institute of Pathology medical examiner for forensic analysis. Burial preparation and arrangements were coordinated with the families by the Port Mortuary at Dover Air Force Base, Delaware. Additional details on the mechanism of injuries sustained by the crew and lessons learned for enhanced crew survival are found in the Columbia Crew Survival Investigation Report NASA/SP-2008-565.

Reconstruction of the Columbia from parts found in East Texas. From this layout, NASA was able to determine that a large hole occurred in the leading edge of the wing and identify the burn patterns that eventually led to the destruction of the shuttle.

Making the boosters and main engines more robust became extremely important for engineers at MSFC and Thiokol. The engineers and astronauts at JSC threw themselves into developing an escape system and protective launch and re-entry suits and improving the flight preparation process. All of the improvements then had to be incorporated into the KSC vehicle processing efforts.

All NASA centers concentrated on how they could make the system better and safer. For civil servants and contractors, the recovery from the accident was not just business. It was personal. Working toward Return to Flight was almost a religious experience that restored the shattered confidence of the workforce.

NASA instituted a robust flight preparation process for the Return to Flight mission, which focused on safety and included a series of revised procedures and processes at the centers. At KSC, for instance, new policies were instituted for 24-hour operations to avoid the fatigue and excessive overtime noted by the Rogers Commission. NASA implemented the NASA Safety Reporting System. Safety, reliability, maintainability, and quality assurance staff increased considerably.

JSC's Mission Operations Director Eugene Kranz noted that Mission Operations examined "every job we do" during the stand down. They microscopically analyzed their processes and scrutinized those decisions. They learned that the flight readiness process prior to the Challenger accident frequently lacked detailed documentation and was often driven more by personality than by requirements. The process was never identical or exact but unique. Changes were made to institute a more rigorous program, which was well-documented and could be instituted for every flight.

Astronaut Robert Crippen became the deputy director of the National Space Transportation System Operations. He helped to determine and establish new processes for running and operating the flight readiness review and mission management team (headed by Crippen), as well as the launch commit criteria procedures, including temperature standards. He instituted changes to ensure the agency maintained clear lines of responsibility and authority for the new launch decision process he oversaw.

Retired Astronaut Richard Truly also participated in the decision-making processes for the Return to Flight effort. Truly, then working as associate administrator for spaceflight, invited the STS-26 (1988) commander Frederick Hauck to attend any management meetings in relation to the preparation for flight. By attending those meetings, Hauck had "confidence in the fixes that had been made" and "confidence in the team of people that had made those decisions," he remarked.

Return to Flight After Challenger Accident

As the launch date for the flight approached, excitement began to build at the centers. Crowds surrounded the shuttle when it emerged from the Vehicle Assembly Building on July 4, 1988. The Star-Spangled Banner played as the vehicle crawled to the pad, while crew members and other workers from KSC and Headquarters spoke about the milestone. David Hilmers, a member of the crew, tied the milestone to the patriotism of the day. "What more fitting present could we make to our country on the day of its birth than this? America, the dream is still alive," he exclaimed. The Return to Flight effort was a symbol of America's pride and served as a healing moment not only for the agency but also for the country. Tip Talone of KSC likened the event to a "rebirth."

Indeed, President Ronald Reagan, who visited JSC in September 1988, told workers, "When we launch Discovery, even more than the thrust of great engines, it will be the courage of our heroes and the hopes and dreams of every American that will lift the shuttle into the heavens."

Without any delays, the launch of STS-26 went off just a few days after the president's speech, returning Americans to space. The pride in America's accomplishment could be seen across the country. In Florida, the Launch Control Center raised a large American flag at launch time and lowered it when the mission concluded. In California, at Dryden Flight Research Center, the astronauts exited the vehicle carrying an American flag—a patriotic symbol of their flight. Cheering crowds waving American flags greeted the astronauts at the crew return event at Ellington Field in Houston, Texas. The launch restored confidence in the program and the vehicle. Pride and excitement could be found across the centers and at contract facilities around the country.

The Columbia Accident

NASA flew 87 successful missions following the Return to Flight effort. As the 1990s unfolded, the post-Challenger political and economic environment changed dramatically.

Environment Changes

As the Soviet Union disintegrated and the Soviet-US conflict that began in the mid 1940s came to an end, NASA (established in 1958) struggled to find its place in a post-Cold War world. Around the same time, the federal deficit swelled to a height that raised concern among economists and citizens. To cut the deficit, Congress and the White House decreased domestic spending, and NASA was not spared from these cuts. Rather than eliminate programs within the agency, NASA chose to become more cost-effective. A leaner, more efficient agency emerged with the appointment of NASA Administrator Daniel Goldin in 1992, whose slogan was "faster, better, cheaper."

The shuttle, the most expensive line item in NASA's budget, underwent significant budget reductions throughout the 1990s. Between 1993 and 2003, the program suffered from a 40% decrease in its purchasing capability (with inflation included in the figures), and its workforce correspondingly decreased. To secure additional cost savings, NASA awarded the Space Flight Operations Contract to United Space Alliance in 1995 to consolidate numerous shuttle contracts into one.

Pressure Leading up to the Accident

As these changes took effect, NASA began working on Phase One of the Space Station Program, called Shuttle-Mir. Phase Two, assembly of the ISS, began in 1998. The shuttle was critical to the building of the outpost and was the only vehicle that could launch the modules built by Europe, Japan, and the United States. By tying the two programs so closely together, a reliable, regular launch schedule was necessary to maintain crew rotations, so the ISS management began to dictate NASA's launch schedule. The program had to meet deadlines outlined in bilateral agreements signed in 1998. Even though the shuttle was not an operational vehicle, the agency worked its schedules as if the space truck could be launched on demand, and there was increasing pressure to meet a February 2004 launch date for Node 2. When launch dates slipped, these delays affected flight schedules.

On top of budget constraints, personnel reductions, and schedule pressure, the program suffered from a lack of vision on replacing the shuttle. There was uncertainty about the program's lifetime. Would the shuttle fly until 2030 or be replaced with new technology? Ronald Dittemore, manager of the Space Shuttle Program from 1999 to 2003, explained, "We had no direction." NASA would "start and stop" funding initiatives, like the shuttle upgrades, and then reverse directions. "Our reputation was kind of sullied there, because we never finished what we started out to do."

This was the environment in which NASA found itself in 2003. On the morning of January 16, Columbia launched from KSC for a lengthy research flight. On February 1, just minutes from a successful landing in Florida, the Orbiter broke up over East Texas and Louisiana. Debris littered its final path. The crew and Columbia were lost.

Recovering Columbia and Her Crew

Recovery of the Orbiter and its crew began at 9:16 a.m., when the ship failed to arrive in Florida. The rapid response and mishap investigation teams from within the agency headed to Barksdale Air Force Base in Shreveport, Louisiana. Hundreds of NASA employees and contractors reported to their centers to determine how they could help bring the crew and Columbia home. Local emergency service personnel were the first responders at the various scenes. By that evening, representatives from local, state, and federal agencies were in place and ready to assist NASA.

The recovery effort was unique, quite unlike emergency responses following other national disasters. David Whittle, head of the mishap investigation team, recalled that there were "130 state, federal, and local agencies" represented in the effort; but as he explained, we "never, ever had a tiff. Matter of fact, the Congressional Committee on Homeland Security sent some people down to interview us to figure out how we did that, because that was not the experience of 9/11." The priority of the effort was the recovery of the vehicle and the astronauts, and all of these agencies came together to see to it that NASA achieved this goal.

While in East Texas and Louisiana, the space agency came to understand how important the Space Shuttle Program was to the area and America. Volunteers traveled from all over the United States to help in the search. People living in the area opened their arms to the thousands of NASA employees who were grieving. They offered their condolences, while some local restaurants provided free food to workers. Ed Mango, KSC launch manager and director of the recovery for approximately 3 months, learned "that people love the space program and want to support it in any way they can." His replacement, Jeff Angermeier, added, "When you work in the program all the time, you care deeply about it, but it isn't glamorous to you. Out away from the space centers, NASA is a big deal."

As volunteers collected debris, it was shipped to KSC where the vehicle was reconstructed. For the center's employees, the fact that Columbia would not be coming back whole was hard to swallow. "I never thought I'd see Columbia going home in a box," said Michael Leinbach of KSC. Many others felt the same way. Working with the debris and reconstructing the ship did help, however, to heal the wounds.

As with the loss of Challenger, NASA employees continue to be haunted by questions of "what if." "I'll bet you a day hardly goes by that we don't think about the crew of Columbia and if there was something we might have been able to do to prevent" the accident, admitted Dittemore. Wayne Hale, shuttle program manager for launch integration at KSC, called the decisions made by the mission management team his "biggest" regret. "We had the opportunity to really save the day, we really did, and we just didn't do it, just were blind to it."

Causes

Foam had detached from the ET since the beginning of the program, even though design requirements specifically prohibited shedding from the tank. Columbia sustained major damage on its maiden flight, eventually requiring the replacement of 300 tiles. As early as 1983, six other missions witnessed the left tank bipod ramp foam loss that eventually led to the loss of the STS-107 crew and vehicle. For more than 20 years, NASA had witnessed foam shedding and debris hits. Just one flight after STS-26 (the Return to Flight after Challenger), Atlantis was severely damaged by debris that resulted in the loss of one tile.

Two flights prior to the loss of Columbia and her crew, STS-112 (2002) experienced bipod ramp loss, which hit both the booster and tank attachment ring. The result was a 10.2-cm- (4-in.)-wide, 7.6-cm- (3 in.)-deep tear in the insulation. The program assigned the ET Project with the task of determining the cause and a solution. But the project failed to understand the severity of foam loss and its impact on the Orbiter, so the due date for the assignment slipped to after the return of STS-107.

Foam loss became an expected anomaly and was not viewed as risky. Instead, the issue became one the program had regularly experienced, and one that engineers believed they understood. It was never seen as a safety issue. The fact that previous missions, which had experienced severe debris hits, had successfully landed only served to reinforce confidence within the program concerning the robustness of the vehicle.

After several months of investigation and speculation about the cause of the accident, investigators determined that a breach in the tile on the left wing led to the loss of the vehicle. Insulation foam from the ET's left bipod ramp, which damaged the wing's reinforced carbon-carbon panel, created the gap. During re-entry, superheated air entered the breach. Temperatures were so extreme that the aluminum in the left wing began to melt, which eventually destroyed it and led to a loss of vehicle control. Columbia experienced aerodynamic stress that the damaged airframe could not withstand, and the vehicle eventually broke up over East Texas and Louisiana.

Senior program management had been alerted to the STS-107 debris strike on the second day of the flight but had failed to understand the risks to the crew or the vehicle. No one thought that foam could create a hole in the leading edge of the wing. Strikes had been within their experience base. In short, management made assumptions based on previous successes, which blinded them to serious problems. "Even in flight when we saw (the foam) hit the wing, it was a failure of imagination that it could cause the damage that it undoubtedly caused," said John Shannon, who later became manager of the Space Shuttle Program. Testing later proved that foam could create cracks in the reinforced carbon-carbon and holes of 40.6 by 43.2 cm (16 by 17 in.).

Aside from the physical cause of the accident, flaws within the decision-making process also significantly impacted the outcome of the STS-107 flight. A lack of effective and clear communication stemmed from organizational barriers and hierarchies within the program. These obstacles made it difficult for engineers with real concerns about vehicle damage to share their views with management. Investigators found that management accepted opinions that mirrored their own and rejected dissent.

Changes

The second Return to Flight effort focused on reducing the risk of failures documented by the Columbia Accident Investigation Board. The focus was on improving risk assessments, making system improvements, and implementing cultural changes in workforce interaction. In the case of improved risk assessments, Hale explained, "We [had] reestablished the old NASA culture of doing it right, relying more on test and less on talk, requiring exacting analysis, doing our homework." As an example, he cited the ET-120, which was to have been the Return to Flight tank for STS-114 and was to be sent to KSC late in 2004. But, he admitted, "We knew there [were] insufficient data to determine the tank was safe to fly." After the Debris Verification Review, management learned that some minor issues still had to be handled before these tanks would be approved for flight.

During the flight hiatus, NASA upgraded many of the shuttle's systems and began the process of changing its culture. Engineers redesigned the boosters' bolt catcher and modified the tank in an attempt to eliminate foam loss from the bipod ramp. Engineers developed an Orbiter Boom Sensor System to inspect the tiles in space, and NASA added a Wing Leading Edge Impact Detection System. NASA also installed a camera on the ET umbilical well to document separation and any foam loss.

Finally, NASA focused on improving communication and listening to dissenting opinions. To help the agency implement plans to open dialogue between managers and engineers, from the bottom up, NASA hired the global safety consulting firm Behavioral Science Technology, headquartered in Ojai, California.

Return to Flight After Columbia Accident

When the crew of STS-114 finally launched in the summer of 2005, it was a proud moment for the agency and the country. President George W. Bush, who watched the launch from the Oval Office's dining room, said, "Our space program is a source of great national pride, and this flight is an essential step toward our goal of continuing to lead the world in space science, human spaceflight, and space exploration." First Lady Laura Bush and Florida

Witness Accounts—Key to Understanding Columbia Breakup

The early sightings assessment team—formed 2 days after the Space Shuttle Columbia accident on February 1, 2003—had two primary goals:

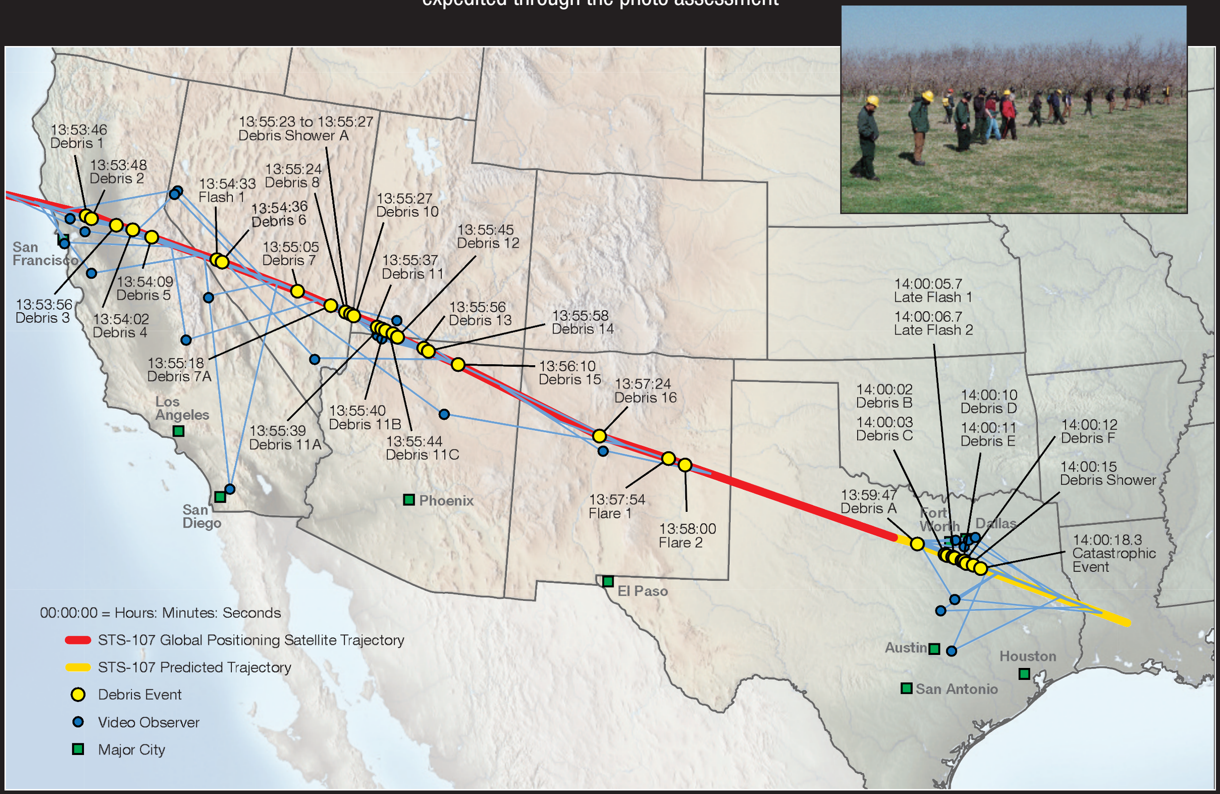
- Sift through and characterize the witness reports during re-entry.
- Obtain and analyze all available data to better characterize the pre-breakup debris and ground impact areas. This included providing the NASA interface to the Department of Defense (DoD) through the DoD Columbia Investigation Support Team.

Of the 17,400 public phone, e-mail, and mail reports received from February 1 through April 4, more than 2,900 were witness reports during re-entry, prior to the vehicle breakup. Over 700 of those included photographs or video. Public imagery provided a near-complete record of Columbia's re-entry and video showed debris being shed from the shuttle. Final analysis revealed 20 distinct debris shedding events and three flashes/flares during re-entry. Analysis of these videos and corresponding air traffic control radar produced 20 pre-breakup search areas, ranging in size from 2.6 to 4,403 square km (1 to 1,700 square miles) extending from the California-Nevada border through West Texas.

To facilitate the trajectory analysis, witness reports were prioritized to process re-entry imagery with precise observer location and time calibration first. The process was to time-synchronize all video, determine the exact debris shedding time, measure relative motion, determine ballistic properties of the debris, and perform trajectory analysis to predict the potential ground impact areas or footprints. Key videos were hand carried, expedited through the photo assessment team, and put into ballistic and trajectory analysis as quickly as possible. The Aerospace Corporation independently performed the ballistic and trajectory analysis for process verification.

The public reports, which at first seemed like random information, were in fact a diamond in the rough. This information became invaluable for the search teams on the ground. The associated trajectory analyses also significantly advanced the study of spacecraft breakup in the atmosphere and the subsequent ground impact footprints.

After the Columbia broke apart over East Texas, volunteers from federal agencies, as well as members of the East Texas First Responders, participated in walking the debris fields, forest, and wetlands to find as many parts as possible. This facilitated in determining the cause of the accident.



Governor Jeb Bush were among the guests at KSC. Indeed, the Return to Flight mission had been a source of pride for the nation since its announcement. For instance, troops in Iraq sent a “Go Discovery” banner that was hung at KSC. At the landing at Dryden Flight Research Center, the astronauts exited the vehicle carrying an American flag. When the crew returned to Ellington Field, a huge crowd greeted the crew, waving flags as a symbol of the nation’s accomplishment. Houston Mayor Bill White declared August 10, 2005, “Discovery STS-114 Day.” Standing on a stage, backed by a giant American flag, the crew thanked everyone for their support.

Impact of the Accidents on NASA

The two shuttle tragedies shook NASA’s confidence and have significantly impacted the agency in the long term. At the time of both accidents, the Space Shuttle Program office, astronauts, and flight and launch control teams were incredibly capable and dedicated to flying safely. Yet, from the vantage point of hindsight, these teams overlooked the obvious, allowing two tragedies to unfold on the public stage.

Many of the people directly involved in those flights remain haunted by the realization that their decisions resulted in the loss of human lives. NASA was responsible for the safety of the crew and vehicles, and they failed. The flight control teams who worked toward perfection with the motto of “Failure is not an option” felt responsible and hesitant to make hard decisions. Likewise, the engineering communities at JSC and MSFC, and the KSC team that prepared the vehicles, shared feelings of guilt and shaken confidence.

The fact that these tragedies occurred in front of millions of spectators and elected officials made the aftermath even more difficult for the NASA team. The American public and the elected officials expected perfection. When it was not delivered, the outcry of “How could this have happened?” made the headlines of every newspaper and television newscast and became a topic of concern in Congress. The second accident was harder on the agency because the question was now: “How could this have happened *again*?”

Because of the accidents, the agency had a more difficult challenge in convincing Congress of NASA’s ability to safely fly people in space. That credibility gap made each NASA administrator’s job more difficult and raised doubts in Congress about whether human spaceflight was worth the risk and money. To this day, doubts have not been fully erased on the value of human spaceflight, and the questions of safety and cost are at the forefront of every yearly budget cycle.

In contrast with American politicians, the team of astronauts, engineers, and support personnel that makes human spaceflight happen believes that space exploration must continue. “Yes, there is risk in space travel, but I think that it’s safe enough that I’m willing to take the risk,” STS-114 (2005) Commander Eileen Collins admitted before her final flight. “I think it’s much, much safer than what our ancestors did in traveling across the Atlantic Ocean in an old ship. Frankly, I think they were crazy doing that, but they wanted to do that, and we need to carry on the human exploration of the universe that we live in. I’m honored to be part of that and I’m proud to be part of it. I want to be able to hand on that belief or enthusiasm that I have to the younger generation because I want us to continue to explore.”

Without this core belief, the individuals who picked up the pieces after both accidents could not have made it through those terrible times. All of the human spaceflight centers—KSC, MSFC, and JSC—suffered terribly from the loss of Challenger and Columbia. The personnel of all three centers recovered by rededicating themselves to understanding what caused the accidents and how accidents could be prevented in the future. Together, they found the problems and fixed them.

Did the agency change following these two accidents? The answer is absolutely. Following the Challenger accident, the teams looked at every aspect of the processes used to prepare for a shuttle mission. As a result, they went from the mentality that every flight was completely new with a custom solution to a mindset that included a documented production process that was repeatable, flight after flight. The flight readiness process evolved from a process of informally asking each element if all was flight ready to a well-documented set of processes that required specific questions be answered and documented for presentation to management at a formal face-to-face meeting. A rigorous process emerged across the engineering and the operations elements at the centers that made subsequent flights safer.

Yet in spite of all the formal processes put in place, Columbia was still lost. These procedures were not flawed, but the decision-making process was flawed with regard to assessing the loss of foam. Tommy Holloway, who served for several years as the Space Shuttle Program manager, observed that the decision to fly had been based on previous success and not on the analysis of the data.

Since 2003, NASA has gone to great lengths to improve the processes to determine risk and how the team handles difficult decisions. A major criticism of NASA following the Columbia accident was that managers did not always listen to minority and dissenting positions. NASA has since diligently worked toward transforming the culture of its employees to be inclusive of all opinions while working toward a solution.

In hindsight, NASA should not have made an "OK to fly" decision for the final missions of Challenger and Columbia. NASA depended on the requirements that went into the Launch Commit Criteria and Flight Rules to assure that the shuttle was safe to fly. Since neither flight had a "violation" of these requirements, the missions were allowed to proceed even though some people were uncomfortable with the conditions. As a result, NASA has emphasized that the culture should be "prove it is safe" as opposed to "prove it is unsafe" when a concern is raised. The process is better, and the culture is changing as a result of both of these accidents.

As a tribute to the human spirit, teams did not quit or give up after either accident but rather pressed on to Return to Flight each time with a better-prepared and more robust vehicle and team. Some individuals never fully recovered, and they drifted away from human spaceflight. The majority, however, stayed with a renewed vigor to find ways to make spaceflight safer. They still believe in the creed "Failure is not an option" and work diligently to meet the expectation of perfection by the American people and Congress.

NASA has learned from past mistakes and continues on with ventures in space exploration, recognizing that spaceflight is hard, complex, and—most importantly—will always have inherent risk. Accidents will happen, and the teams will have to dig deep into their inner strength to find a way to recover, improve the system, and continue the exploration of space for future generations.

On an Occasion of National Mourning

Howard Nemerov
Poet Laureate of the United States
1963-1964 and 1988-1990

It is admittedly difficult for a whole
Nation to mourn and be seen to do so, but
It can be done, the silvery platitudes
Were waiting in their silos for just such
An emergent occasion, cards of sympathy
From heads of state were long ago prepared
For launching and are bounced around the world
From satellites at near the speed of light,
The divine services are telecast
From the home towns, children are interviewed
And say politely, gravely, how sorry they are,
And in a week or so the thing is done,
The sea gives up its bits and pieces and
The investigating board pinpoints the cause
By inspecting bits and pieces, nothing of the sort
Can ever happen again, the prescribed course
Of tragedy is run through omen to amen
As in a play, the nation rises again
Reborn of grief and ready to seek the stars;
Remembering the shuttle, forgetting the loom.